Marine Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

UK public perceptions of Ocean Acidification – The importance of place and environmental identity

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ARTICLE INFO

Keywords:
Ocean Acidification
Public perceptions
Risk communication

ABSTRACT

The marine environment is affected by climate change in many ways but it is also affected by the separate problem of ocean acidification (OA). Anthropogenic carbon dioxide that is absorbed by the ocean causes changes in ocean chemistry including an increase in acidity. Fisheries and shellfish industries, which are vital livelihoods for some communities have already been affected by OA. As there has been little research conducted to examine public risk perceptions of this issue, the aim was to explore this through a survey (N = 954) carried out in the UK. The survey explored a range of psychological factors including concern, place attachment, and environmental identity that are known to influence risk perceptions. A regression analysis found that more concerned participants had stronger environmental identities and higher levels of knowledge about OA. As predicted, they also felt more attached to the ocean and felt more negative about OA. It was clear that place attachment and environmental identity were important factors and thus should not be neglected when developing risk communications, particularly for this unfamiliar risk issue. As unfamiliar and complex risks such as OA are becoming more prevalent and must be communicated successfully in a world full of conflicting information, it is important to consider how OA is perceived by the public and how this can inform policy decisions in future. If major mitigation and adaptation strategies are adopted by policymakers the success of these will also ultimately require society to accept them.

1. Introduction

The effects of climate change on the marine environment are already visible in parts of the world. Climate tipping points in the Earth system have been identified [1] where a small change can result in a state change to the system. The most recent Intergovernmental Panel on Climate Change (IPCC) report [2] dedicated a section to the impact of climate change on the oceans, establishing a variety of stressors the ocean faces including the effects of ocean warming, deoxygenation and OA. The potential effects of OA on marine biodiversity for various future emissions scenarios has been reviewed generally showing decreased rates of survival, calcification, growth, development and abundance of organisms [3,4]. Although the science is complicated, many potentially negative impacts have been identified such that OA is widely considered a serious threat to marine ecosystems and services, especially if global carbon emissions are not quickly brought under control [5]. Unlike in previous international negotiations, the problem of OA was widely discussed leading up to the 2015 Paris Agreement on Climate Change [6], which notes the importance of ensuring the integrity of marine ecosystems in its text [7].

However, research to understand public perceptions of OA is still very limited, and there has been little public engagement about this issue within the UK or elsewhere. The UK is responsible for biodiversity in its Overseas Territories with some of these regions at risk from OA as many of them are islands in vulnerable areas. For example the Pitcairn Islands (with one of the largest marine nature reserves in the world) has a strong tourism industry driven by the attraction of warm-water coral reefs [8].

The UK itself is also directly at risk from OA, although it is hard to determine exactly what the impacts might be and how serious they could be. Recent research has shown that OA could be detrimental across the UK fishing industry and associated industries particularly alongside ocean warming [9]. Goods and services from the UK marine environment include multi-million pound fisheries, aquaculture industries and raw materials (fishmeal, fish oil and seaweed), which are necessary to feed fish species that are being intensively produced [10]. As well as these production services there are significant economic and cultural services including leisure and recreation that are reliant on the

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https://doi.org/10.1016/j.marpol.2018.04.006
Received 19 March 2018; Accepted 4 April 2018
0308-597X/

biodiversity of the marine environment [11]. In 2009 there was no UK legislation that directly addressed OA [12] though it has been acknowledged, alongside climate change, as something that must be considered and researched (as seen by the UK Ocean Acidification programme [13] and a recent enquiry by the UK House of Commons Science and Technology Committee [14]).

There is also a pressing need to involve the public with OA, particularly as the issue becomes more widely discussed in relation to CO_2 emission targets and the wider topic of climate change. As some of the solutions for minimising the effects of OA may differ from those proposed for climate change more generally, involving the public in constructive dialogue about this risk issue and possible remediation technologies and policies through upstream engagement methodologies will help promote action rather than just provide information [15]. Through effective dialogue around OA, the values people hold and the possible wider societal implications that OA may have will mean public engagement can move away from simply understanding mental representations and raising awareness, to incorporating their citizen's preferences into proposed solutions and actions [16].

2. Background

2.1. Public perceptions of climate change

As OA is often seen as a subset of climate change, it is expected that the literature on perceptions of climate change will be closely linked to that of OA. Public understanding of climate change is crucial as it contributes to people's response to government policy and initiatives designed to help adapt to and mitigate climate change [17]. The recent IPCC Fifth Assessment Report (AR5) made the strongest statement yet that humans are responsible for climate change: “It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century” [2]. There have also been successive global record temperatures each following year, with 2016 announced as the warmest year on record since records began [18]. There is an overwhelming scientific consensus of climate scientists [19] and extensive evidence of the impacts of climate change, such as coral reef damage and impacts in the Arctic such as a reduction in glacial ice mass and thawing of permafrost [20,21]. A recent literature review showed how public perceptions of climate change have changed over time [22]. In the 1980s and 1990s there was a growth in awareness and concern globally as there was more evidence and media coverage on climate change. As media attention increased in the mid-2000s, this awareness was more widespread and there was consensus that action was needed. However, in the latter 2000s and early 2010s doubts and scepticism increased in the public as climate change became a more politicised issue in the US in particular [23]. Risk perceptions predict behavioural intentions and can help determine if people would be likely to take action on environmental risk issues such as climate change [24]. There is a well-established literature exploring a number of barriers to public engagement with climate change [25,26], including lack of action from government or industry and lack of knowledge. The lack of public support has frequently been blamed on deficits in knowledge or poor understanding of the issue. Although knowledge does have a role to play here, it is not just about the scientific facts of climate change, but also how those understandings are held within social, cultural and political contexts [27,28]. By approaching people simply as ‘rational actors’, the importance of social issues such as the personal values and identities people ascribe to are given little consideration.

Alongside the literature on specific climate change perceptions there is a growing body of research exploring attitudes and understandings in relation to the marine environment. Opinion polls carried out by the Ocean Project and AAAS (American Association for the Advancement of Science) in 1999 and 2003 respectively, showed respondents were aware that human activities impacted on the ocean, but did not see urgent action as being necessary [29]. Understanding the water and carbon cycles were seen as important to aid people's comprehension of the ocean and improve their climate science literacy; those who were more knowledgeable were more supportive of policies to protect the ocean. Jefferson and colleagues [30] surveyed the UK public to assess their perceptions of the marine environment; more specifically marine health and knowledge of subtidal species. Issues such as litter and other indicators of cleanliness scored highest, as did contaminated seafood when examining marine health perceptions. The authors go on to suggest that these are clearly linked to human impact on the marine environment. When respondents were asked to select risks to the health of marine environments, the most severe risks such as the effects of climate change were not selected possibly because they do not appear to be clearly linked to harming human health [30]. Other research also finds that the public do not identify as important the same marine issues that scientists prioritise, though climate change is recognised as an issue [31].

2.2. Public perceptions of Ocean Acidification

There has been work exploring stakeholder perceptions of OA, which has shown that fishermen and the shellfish industry are aware of OA and are very concerned about it [32,33]. OA has already affected the Northwest Pacific [34] where oyster hatcheries are important for the shellfish industry [35]. Mabardy and colleagues [32] surveyed people in the US West Coast shellfish industry to assess level of concern through negative impacts of OA and participants’ understanding of the risk. 94% of respondents had heard of OA with over half having experienced the impacts of OA; 97% experienced financial impacts and 68% emotional impacts. Concern about OA was measured on a 5-point scale (extremely concerned, very concerned, somewhat concerned, not too concerned, not at all concerned). Researchers found that 64% of respondents were extremely to very concerned about OA if they had not experienced OA and 93% were equally concerned if they had personally experienced the impacts of OA. Finally, over three-quarters of the sample were extremely to very concerned about OA regardless of their level of understanding.

Donkersloot [33] carried out roundtable discussions in Southern Alaska to gather the thoughts and experiences about OA from industries, fishing families and communities to ensure that they could help inform public policy on OA. In these discussions there was recognition of a need for research into OA in Alaska waters to continue and expand, including monitoring ocean conditions and changes in water samples. Fishermen acknowledged their unique positioning to assist with research but were also frustrated that the impacts were unclear and unlikely to be acted upon until they were causing problems. Respondents felt as though action needed to be led by them but also highlighted the need for political level action. This included both local government action and trying to inform fisheries policy. Lastly, although the economic case for OA more generally is important, the impacts are more personal for families, cultures etc. such as those involved in the discussions. Accordingly, OA can be a prominent issue for those who are directly involved in affected industries but this may not transfer to wider society (Table 1)

One of the few pieces of research specifically focused on public perceptions of OA was carried out in Alaska. This region is more vulnerable to OA because of the cool water temperatures and the ocean circulation pattern. The region also has a strong fisheries industry, which is of key importance to the economy. Frisch and colleagues [36] surveyed Alaskan residents (N = 311) and found that many individuals had a low level of understanding regarding OA and the associated risks. This was expected as they acknowledged that OA was an unknown risk issue for those in the wider community. Three-quarters of respondents had heard of OA and cited CO_2 as the main cause with the second most cited being human activity. They also found that 52% of the sample was concerned about OA and concern increased in those already concerned for future projections of 100 years into the future. When comparing this

Table 1
Summary of participant demographics.

		Sample
Gender (%)	Male	54
	Female	46
Age (%)	18–24	6.3
	25–34	18.2
	35–44	17.8
	45–54	19
	55–64	15.9
	65–74	8.8
	75+	14
Education (%)	Bachelor's degree/equivalent or higher	32.5

to the levels of concern and awareness about OA to those who work in the shellfish industries there is a difference, with Alaskan residents not as concerned or aware of the risk. Mabardy et al. [32] believe this is because stakeholder groups recognise OA and have first-hand experience with it whereas the residents surveyed in Frisch et al. [36] have not experienced the impacts of OA.

The levels of awareness found by Frisch et al. [36] are very different from those found by Capstick and colleagues [37] who report that only one in five had heard of OA with only 37.5% citing CO_2 as the cause (34.1% cited pollution as the main cause). This latter work surveyed a UK-based sample whom it could be argued have less of a reliance on the ocean than the Alaskan sample, which may account for the difference in awareness of OA, although the issue was also far more widely reported in Alaska. Capstick et al. [37] also found high levels of concern about OA as well as strong negative associations (e.g. harm to organisms and/or humans) with OA.

2.3. Environmental identity and place attachment

There are clear cultural worldviews and ideologies linked to how people perceive climate change and these are expected to be similar for OA as in Capstick et al. [37]. As set out in the cultural theory of risk [38], those who ascribe to an egalitarian worldview perceive more environmental risks than those who are more individualistic [39]. The role of identity as part of values has been shown to shape climate engagement as it has an effect on how climate change information is interpreted [40]. Environmental identity can be defined as "the set of meanings attached to the self as the person interacts with the natural environment" such as whether someone feels protective of the environment or is "environmentally friendly" [41]. People with a strong environmental identity have been found to be more likely to carry out a set of pro-environmental behaviours than those with a weaker environmental identity [42]. Place attachment and place identity can also contribute positively to public communication and engagement with climate change [43]. Place attachment refers to the formation of an emotional connection with a particular location [44] and place identity refers to when a place comes to be viewed as an important part of one's self [45]. It is important to consider how attachment affects support for new mitigation and adaptation projects, for example, as shown by Devine-Wright and Howes [46]. When asked about proposed wind farms, place identity was found to be threatened for those strongly bonded to a place increasing opposition to such plans.

Being in a natural environment, even only briefly, is associated with feelings of happiness and improved well-being [47]. People also report feeling more restored after visits to coastal environments than open countryside [48] or viewing nature scenes rather than window views of green space [49]. White and colleagues [50] show that water in a natural environment is seen as more positively affective and is generally preferred to a built environment absent of any water features. Affect refers to a feeling that something is good or bad forming part of the experiential system of risk analysis, which produces an intuitive and automatic response (see [51]). In this context, it is expected that when marine environments are threatened people will express high levels of concern. It is hypothesised that for people who have a strong emotional connection to the ocean OA will be a more serious issue. It is also predicted that if people have a stronger environmental identity or feel more attached to the ocean they will be more concerned about OA. The impacts of OA will contribute to the debate around how to reduce carbon emissions and it is important that the public have a role in shaping policy and can make an informed contribution. By establishing what drives risk perceptions of OA it will become clearer how this risk issue is understood, and future risk communication or public engagement can start to be addressed in an evidence-based manner [52], and with more emphasis placed on the importance of emerging risks.

3. Methods

3.1. Participants

An online survey (N = 954) was carried out in March 2016 with UK participants identified using a recruitment agency that specialises in online panels. Recruitment involved participants already held on a confidential database by the recruitment agency and in accordance with the Market Research Society Code of Conduct. Participants can then decide whether or not to take part and are remunerated via an arrangement with the recruitment agency. The aim was to obtain a fully nationally representative sample. However in the survey data eventually collected, men were slightly overrepresented in the sample (54% compared to 46% of women). For level of education those with a degree or above were underrepresented (32.5% of the sample), with 67.5% educated to below degree level.

3.2. Survey design

Participants were asked questions to assess their level of knowledge about OA including the causes, impacts, responses and interactions (adapted from [37]). These items were asked to help understand what information people knew about OA. A scale of 'Strongly Agree' to 'Strongly Disagree' was used for most of these items. Each had a number of possible statements for participants to select whether they agreed or not on the causes, impacts, and interactions. They were also asked to select one of the possible options as the one they thought was most likely to be the cause, consequence and appropriate response to OA. A knowledge score was assigned to each participant based on how many statements they correctly identified. Each statement presented to participants was independently assessed by two experts (Earth System Modeller and Paleoclimatologist) as to whether it was scientifically correct or not based on the evidence or future projections.

Participants were also asked to respond on a five-point scale from strongly agree to strongly disagree for each statement on how attached they felt to the ocean, as well as statements assessing their cultural worldviews and environmental identities (see Table 2). They were asked about their level of concern in relation to OA as well as how OA made them feel as a whole on a five point scale from 'Very Bad' - 'Very Good'.

4. Results

4.1. Awareness and knowledge of OA

As seen in previous surveys, there was low awareness of OA as predicted with only 29.4% saying they had heard of OA (see Table 3).

There was also a low level of knowledge with pollution from chemical and industrial waste thought to be the main cause of OA (78.3% of sample) although three quarters of people recognised that damage to coral reefs, impacts on marine organisms and food chains were most likely to occur from OA. Participants thought that the best response to

Table 2
Scale items included in the survey. Multi-scale items were used to test each underlying construct with each set of items subject to a factor analysis to test the reliability and validity of each measure.

Egalitarianism
In my ideal society, all basic needs such as food, housing, education and health care would be guaranteed by the government for everyone
Discrimination against minorities is still a very serious problem in our society
The world would be a better place if its wealth were divided equally among nations
Individualism
When I have problems, I try to solve them on my own
If the government spent less time trying to fix everybody's problems we'd all be better off
People should be allowed to make as much money as they can for themselves, even if others are not able to
Pro-environmentalism
I think of myself as someone who is concerned about the environment
I consider myself to be environmentally conscious
Being environmentally- friendly is an important part of who I am
Place attachment
The ocean is the best place for what I like to do
I feel the ocean is a part of me
Visiting the ocean says a lot about who I am
I identify very strongly with the ocean
I am very attached to the ocean
I get more satisfaction out of visiting the ocean more than any other place
The ocean is very special to me
No other place can compare to the ocean

Table 3
Self-reported awareness of OA at time of survey in 2016.

Have you heard of ocean acidification before today?	**% 2016**
Yes	29.4
No	70.6

reduce OA would be to reduce pollution (27.3%) with only 12.7% selecting the reduction of carbon emissions.

4.2. Concern about OA

In the survey, participants were also asked how concerned they were about OA (see Fig. 1). 43.9% of participants were either very concerned or fairly concerned about OA with a further 31.1% answering that they were a little concerned; showing that concern about OA is high in the wider population as expected.

Finally, concern about OA was explored through a regression analysis to see what predicted concern for this novel risk issue. Previous literature on climate change risk perceptions find that concern is influenced by numerous variables and those findings are expected to be similar for the risk of OA.

The first regression model (Table 4) was not particularly significant in predicting concern about OA when only demographics were entered; with only gender a unique significant predictor. The second model, however, accounted for a full 32% of the variability in the concern scores, with place attachment the strongest predictor of concern ($\beta = -.25$, $p < .00$) as participants who felt more strongly attached to the ocean were also more concerned about OA than those who did not feel a connection to the ocean. Those who scored more highly on the knowledge test were more likely to be more concerned about OA ($\beta = .23$, $p < .00$), as were those who had strong pro-environmental identities ($\beta = .19$, $p < .00$) and those who expressed a more egalitarian worldview ($\beta = .08$, $p < .01$). By contrast, individualism was a weak scale item and was not a significant predictor in this model. Emotion was also significant ($\beta = -.11$, $p < .00$) with concern in OA increasing as people felt more negative about it. Finally, those with a postgraduate degree were also more likely to be concerned about OA ($\beta = .07$, $p < .05$).

Table 4
Regression results for concern about OA The *p* value shown is the probability of obtaining the observed result when no true effect exists. β corresponds to standardized beta coefficients. R^2 is the proportion of variance for concern about OA explained by all predictor variables in each model. ΔR^2 refers to the change in variance.

Predictor	**Model 1 -Demographics** β	**Model 2 – Values, environmental identity, attachment, knowledge & emotion** β
Gender	**−0.08***	0.02
Age (45 – 54)		
18–24	−0.01	.01
25–34	−0.09	−0.07
35–44	−0.05	−0.04
55–64	−0.04	−0.04
65–74	−0.03	−0.01
75+	0.01	0.01
Education (no qualifications)		
GCSE	−0.01	−0.04
A-levels	.00	−0.03
Degree	−0.04	−0.03
Postgraduate	0.05	**0.07***
Egalitarianism	–	**0.08***
Individualism	–	−0.04
Environmental Identity	–	**0.19*****
Place attachment	–	**−0.25*****
Knowledge score	–	**0.23*****
Emotion	–	**−0.11****

$R^2 = .02$ for Step 1, $\Delta R^2 = .32$ for Step 2.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

5. Discussion

In this sample, although there were low levels of awareness and knowledge about OA, there were high levels of concern found among those surveyed. This corresponds with earlier findings of Capstick et al. [37], where low awareness around OA was still accompanied by concern about the issue. As anticipated place attachment was the strongest predictor in the regression analysis on concern. This emotional attachment to the ocean was unsurprising as the ocean is frequently associated with leisure and tourism and is important for many livelihoods. The impacts of OA have already affected people living on the US West Coast including Alaska, where these impacts are both personal and have been economically damaging [33]. This population is

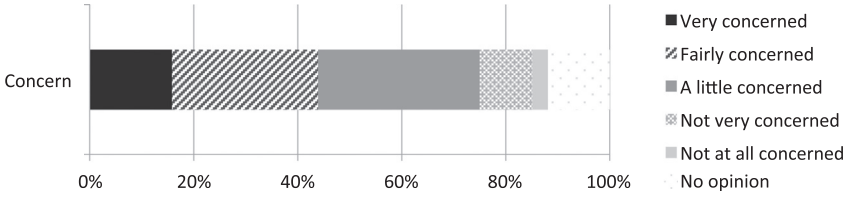

Fig. 1. Responses to 'To what extent are you concerned about OA' from survey data.

attached to the ocean because people rely on marine resources, and marine impacts could potentially cause serious issues for people. Under such circumstances OA is local and more 'visible' to those who are experiencing it, but this is not likely to be the case for wider society. The ocean also provides a positive and restorative environment for people [47] so threats to this environment are likely to concern the public. People feel connected to the ocean and associations tend to be positive with people expressing concern for marine life such as seals, dolphins or whales [53]. People feel an attachment to natural environments with many holding fond memories from childhood holidays at the seaside or observing marine wildlife during boat trips [54,55]. Hinds and Sparks [56] found that participants who had grown up in a rural location identified more with the natural environment, had more positive affective connections and stronger behavioural intentions than those who had grown up in an urban environment. Environmental identity, place and affect have been shown to be important variables in this paper and could be very useful areas to explore in future when considering behavioural changes towards OA.

A key barrier to engaging the public with less visible impacts of climate change like OA is likely to be psychological distancing where risks are perceived to be distant from the individual across different dimensions such as temporally, socially and through geographical distance [25]. Climate risks in particular are seen as more likely to affect people in future generations or in other parts of the world meaning people do not necessarily feel at personal risk or that something is of relevance to them [57]. Here it has been suggested that localising the issue is key, such that it becomes closer in space, time and society as well as less uncertain for people [58]. Although this strategy has to be attempted with care, and more research is needed to explore the validity of this suggestion [59] one way to localise the issue will be through the use of narratives and stories about the impacts of OA in communities reliant on the marine environment (see [60]). OA is not as prominent in the UK as in parts of North America as there have not been significant impacts yet (although these are possible). However, to localise OA in the UK it would be possible to highlight potential (albeit uncertain) impacts on the North Sea [61], which is a vulnerable region partly due to eutrophication [62], thus helping to reduce psychological distancing for the UK public. It is also possible that those who are more attached to the ocean will be more likely to engage with OA, as was found by Scannell and Gifford [43] with climate change. Despite OA being a global issue local actions can lead to broader actions for coastal areas and even small-scale actions in a community are worthwhile [63]. For example legislative action was taken in the Pacific Northwest US to reduce the impacts of the OA that was causing serious problems for communities and local industries. Cooley and colleagues also map out other types of actions such as education in the community to raise concern and supporting marine jobs that may be impacted by OA [63].

The Paris Agreement was seen by many as the last chance to take serious action and limit impacts of climate change and since it has come into force almost all countries have submitted their nationally determined contributions (NDCs) to reduce emissions [7]. As mentioned earlier, OA along with the importance of marine ecosystems was recognised and in these NDCs coastal impacts, warming impacts and fisheries were the main concerns of governments [6]. OA itself was only specifically included by 14 small island developing states but the general move towards addressing marine concerns is a positive one. However some commentators make it clear that the Paris Agreement does not go far enough and emission reductions promised are not sufficient [64]. The assumptions made in the Paris Agreement to achieve a 2 °C scenario also assume successful deployment of negative emission technologies at scale but their credibility has yet to be proven [65].

It is clear that the marine environment is important; particularly the oceans [66]. However, McKinley and Fletcher [67] interviewed a group of marine practitioners from governance organisations around the UK and found that they believed that the public feels disconnected from the marine environment and this was linked to poor awareness of marine issues. The marine practitioners also thought that the public should be involved in marine decision-making and that raising awareness and concern was important. By involving the public, the practitioners believed that citizens will become more engaged with the issues, encouraging changes to lifestyle choices and behaviours.

It will take time for the public and policymakers to understand unfamiliar risks but developing risk communications are not the only strategy that should be adopted. The public engagement strategies used in Science and Technology Studies (STS) could be useful whilst OA is a new and unfamiliar risk [68]. Scholars argue that public engagement is as much about how interests and politics influence risk framing, as it is about ascertaining what constitutes various publics knowledges about 'risk' [69]. Rather than address a perceived knowledge-deficit through standard risk communications the public can in this way be supported in forming their opinions and preferences through informed debate.

Our study also suggests that the continuing low public awareness of the issue must be addressed to ensure support for future governmental policies and the use of new technologies to reduce carbon emissions specifically. This effort should be supplemented by future surveys to demonstrate whether levels and the nature of awareness changes further in the future. However, research has already shown that in order to ensure information provided is effective in engaging the public, it should be tailored for the target group; rather than simply increasing knowledge and concern, effective implementation and adaptation strategies should also be clarified [25].

6. Conclusion

As the impacts of climate change become more apparent over time, it is likely that currently 'hidden' risk issues such as OA will gain greater salience and prevalence within society. Though there are a range of measures in place for tackling climate change, there has been less thought about what to do to minimise OA. It is clear that adapting to climate change is not necessarily a particularly effective strategy for coping with OA. Public engagement needs to become more co-operative and inclusive to encourage motivation to act or encourage political wills in the appropriate way and result in the introduction of policies aimed to mitigate or adapt to the problem of OA.

Acknowledgements

This research was supported by a Cardiff University President's Research Scholarship.

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